*Journal of Athletic Training* 1998;33(4):351-358

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# The Pars Interarticularis Stress Reaction, Spondylolysis, and Spondylolisthesis Progression

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***Objective***: To review the classification, etiology, clinical and radiologic evaluation, and management of the pars interarticularis stress reaction, spondylolysis, and spondylolisthesis progression.

***Data Sources***: Grateful Med was searched from 1980 to 1998 using the terms "spondylolysis," "spondylolisthesis," "female athlete," "spondylogenic," and "pars interarticularis."

***Data Synthesis***: The progression from pars interarticularis stress reaction through spondylolysis to spondylolisthesis is common in adolescent athletes, and, because of hormonal influences and cheerleading and gymnastic maneuvers, females are particularly at risk. Proper diagnosis and management include a thorough evaluation, radiographs (possibly with technetium bone scan or single-photon emission computed tomography), activity modification, dietary counseling, a therapeutic exercise program focusing on proper trunk and hip muscle strength and extensibility balances, and education regarding proper back postures, positioning, lifting mechanics, and jump landings.

***Conclusions/Recommendations***: The athletic trainer plays an integral part in managing this injury progression, particularly with identifying at-risk individuals and intervening appropriately.

***Key Words***: low back pain, female athlete, lumbar vertebra

Back pain is one of mankind's greatest afflictions.[1] Financial compensation for low back pain in the adult work force has stimulated great interest in its treatment.[2] Surprisingly, as many as 36% of school-age children also report low back pain, and 7% seek medical attention.[3] Increased exposure time and sports participation have been correlated with a rise in reported low back pain of various diagnoses among adolescent athletes,[4] now accounting for approximately 5% to 8% of total athletic injuries.[5] More young people and more females are participating in highly competitive athletic programs.[6] Over the 6-year period from 1971 to 1976, female participation in competitive sports increased 94%.[7]

Strenuous training can lead not only to assorted soft tissue injuries but also to symptomatic bony defects in the posterior elements of the lumbar spine, elements otherwise referred to as the pars interarticularis (pars).[8] Factors that commonly predispose young athletes to low back pain include a sudden growth spurt, abrupt increases in training intensity or frequency, improper technique, unsuitable sports equipment or playing surfaces, leg length inequality, poor trunk muscle strength, and poor extensibility of the hamstring and hip flexor muscles.[5] Any changes in the length-tension relationships of any lower extremity muscle with pelvic attachments can have tremendous effects on lumbosacral alignment. These changes often result in accumulated microtrauma at the pars.

The lumbar spine proper consists of 5 pairs of diarthrodial facet joints, each containing a superior and an inferior facet and a capsule (Figure 1). When the junctions between the 12th thoracic and 1st lumbar vertebrae (T12-L1) and between the 5th lumbar and 1st sacral vertebrae (L5-S1) are included, 6 facet joint pairs are located in this region. These facet pairs are located on the vertebral arches.[1] The pars refers to the area of the vertebral arch between the superior and inferior facets.[1] Although injuries to this spinal region are usually the result of repetitive hyperextension and hyperlordosis, a genetically predisposed weak point in the pars has been suggested as the cause of spondylolysis. This predisposition can lead to stress fracture, even from the impact forces of normal upright gait.[9] Although the exact etiology is controversial, repetitive microtrauma to this posterior vertebral sector often expresses itself as a "pars interarticularis stress reaction." When this reaction is not managed correctly, it may progress to spondylolysis and potentially to spondylolisthesis.

Spondylolysis (Figure 2) is most common at the lumbar region, being found in about 5% of Caucasian North American adults and more frequently in certain races, suggesting a possible congenital etiology.[8] The term "lysis" is Greek for "loosening, coming apart, or dissolving."[8] In spondylolysis, the pars loses its bony integrity and dissolves. A bilateral pars defect results in the lumbar vertebra being divided into 2 sections. If these sections separate, the condition is called spondylolisthesis (Figure 3).[1]

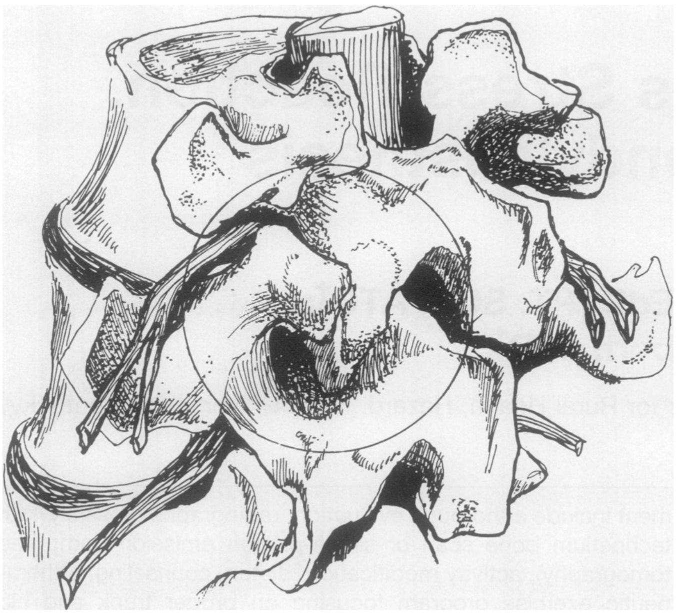

**Figure 1. Typical lumbar facet joint with capsule removed.**

The sequence from the pars interarticularis stress reaction through spondylolysis to spondylolisthesis represents one of the most common bony injury progressions of the athletic spine, with spondylolysis being the primary diagnosis of 47% of adolescent athletes who experience low back pain.[10] A high incidence of lumbar spondylolysis has been reported in football players;[11] however, gymnastics places unparalleled demands on the low back.[12] Reports show that female gymnasts exhibit an incidence of pars defects that is 4 times greater than in a general population of females of comparable age.[11] Jackson et al[12] studied 100 female gymnasts and found that 11% displayed pars defects on lumbosacral radiographs. Females usually have a lower center of gravity than males because of their generally wider pelvis and shorter extremities. While this may be advantageous in sports requiring balance, such as gymnastics and cheerleading, these factors also contribute to injury susceptibility by increasing the likelihood of poor lower extremity alignment, poor lifting and jump-landing mechanics, and potentially greater dependence on the noncontractile components of postural stability.[13] Back injuries in gymnasts can be the result of single or repeated episodes of hyperextension or hyperlordotic positioning and flexion or twisting (Figure 4), which create progressively increased pain with daily activities.[14,15] Common repetitive mechanisms that have been related to lumbar stress fractures are hyperextension, flexion overload,[4] forced rotation,[14] unbalanced shear forces, or these in combination.[8,14] The demands placed on the back from both the dramatic range of motion and the high levels of muscular power required for gymnastics are believed to exceed those of other sports,[15] and more spine injuries occur from gymnastics than from football.[16] Also, the pattern of lumbar vertebral motion that occurs during repetitive jump landings can further exacerbate low back pain, even more so when poor techniques are used.[17,18]

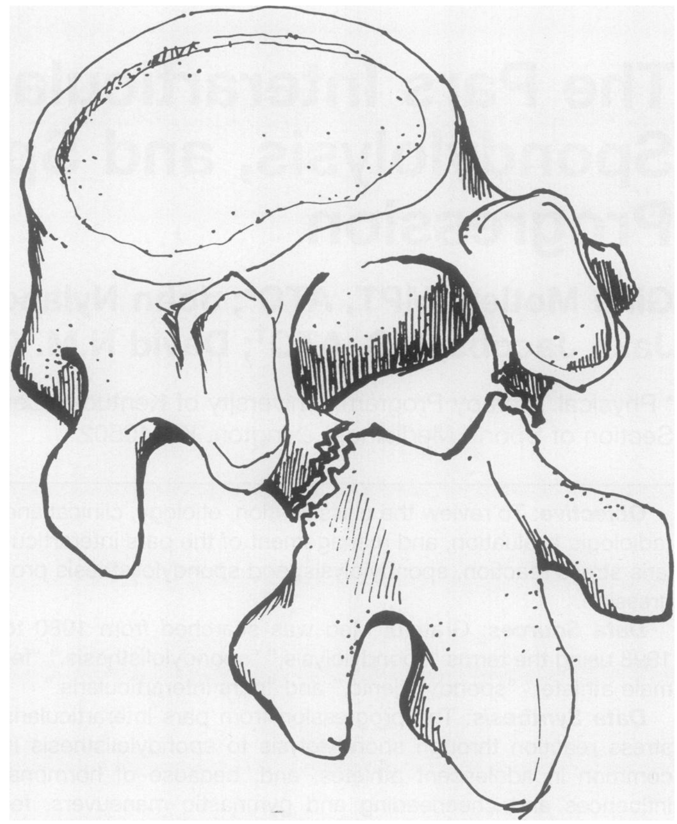

**Figure 2. Spondylolysis of a lumbar vertebra.**

Adolescent females who overtrain to the point of menstrual dysfunction may be risking permanent bone damage. Since girls often begin cheerleading and gymnastic competition before menarche, the harmful effects of hormonal dysfunction may begin without observable risk factors such as menstrual irregularities, altered diet, or low body weight. In a study of female collegiate gymnasts, over 60% met the diagnostic criteria for disordered eating, leading to the conclusion by the author that "disordered eating may be the normative behavior in this population."[19] The hormone imbalances that cause spondylolytic conditions are dependent on the severity, intensity, duration, and interrelationship of risk factors such as family history, menstrual irregularities, excessive exercise, decreased bone mass, poor nutrition/disordered eating patterns, rate of weight loss, and psychological stresses.[20] Certainly, any combination of these factors in conjunction with the performance demands of gymnastics and cheerleading may have considerable effect on the lumbar spine. Preadolescent and adolescent female athletes with menstrual irregularities may suffer irreversible bone mineral density losses if estrogen is not available in sufficient quantities to promote bone growth during this important time in their lives.[21]

## CLASSIFICATIONS AND DEFINITIONS

The term "spondylogenic" refers to low back pain during activity in the absence of all objective signs or other patholo-

**Figure 3. Spondylolisthesis of L5 on S1.**

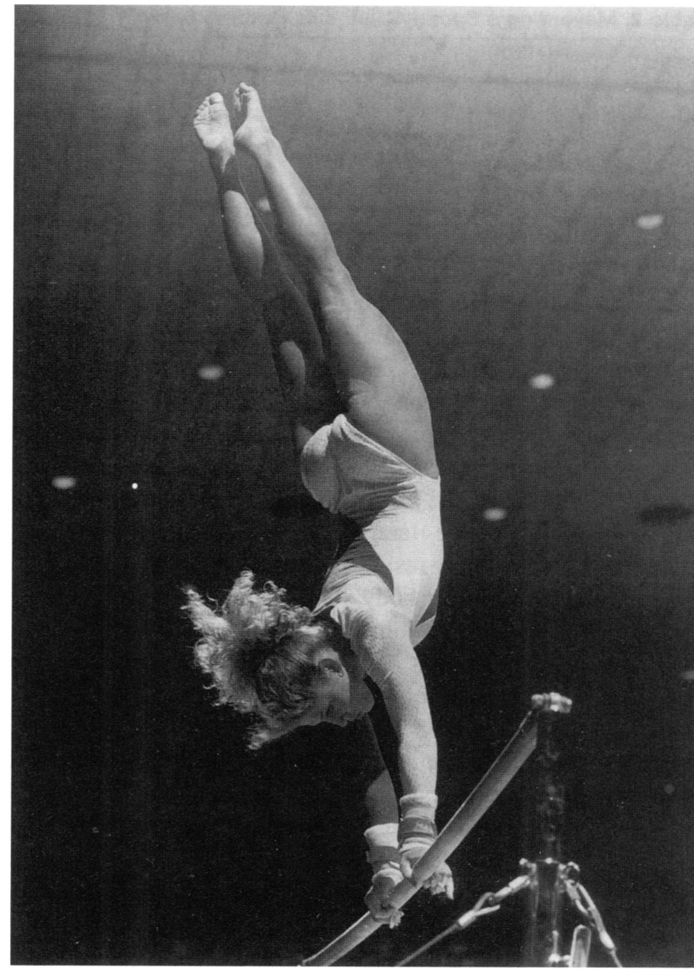

**Figure 4. Combined hyperlordosis and twisting in a gymnast.**

**Table 1. Spondylolisthesis Classifications of Wiltse et al[22]**

| |
|---|
| A. Dysplastic: congenital abnormalities of the upper sacrum or the arch of the fifth lumbar vertebra allow spondylolisthesis to occur |
| B. Isthmic or spondylolytic: a pars interarticularis lesion, which can be a lytic-fatigue fracture of the pars, an elongated but intact pars, or an acute fracture (most common type among adolescent athletes) |
| C. Degenerative: result of a longstanding pars intersegmental instability |
| D. Traumatic: occurs after fractures in other areas of the bony hook (not the pars) |
| E. Pathologic: involves generalized or localized bone disease |

gies. In these patients, both bone scans and radiographs are negative, yet low back pain persists.[8] A pars interarticularis stress reaction refers to a pars stress lesion characterized by negative (normal) radiographs but a positive bone scan. The isthmic classification of pars stress fractures occurs most frequently among adolescent athletes and has been attributed to repeated hyperextension causing shear at the posterior vertebral elements. The fifth lumbar vertebra is affected most often, followed by L4 and then L3. This incidence is increased among participants in sports associated with repetitive flexion-extension activities, such as gymnastics.[14,15]

Wiltse et al[22,23] developed a working classification of spondylolisthesis lesions based on both causal mechanisms and anatomical factors (Table 1). The lesion classification of most concern to the clinician who works with athletes is the isthmic or spondylolytic type of spondylolisthesis. Meyerding[24] developed a grading system for spondylolisthetic lesions based on the magnitude of the "slippage" in relationship to the anteroposterior diameter of the superior aspect of the subjacent vertebra (divided into 4 equal quadrants) (Table 2; Figure 5).

## ETIOLOGY

Aside from their duties of supporting the body's weight and any additional external loads, the intervertebral joints at any instant are subjected to a complex interplay of muscle forces and ligament tension.[25,26] Although the exact mechanism is still unknown, pars injuries are believed to most commonly be the result of repetitive microtrauma.[23] In a balanced upright stance, the spinal column, along with its ligaments and musculature, including the iliopsoas, abdominals, erector spinae, and quadratus lumborum, supports the weight of the upper trunk.[26] Imbalances in trunk musculature strength, endurance,

**Table 2. Meyerding's Spondylolisthesis Grading System[24]**

| Grade | Displacement |
|---|---|
| I | ≤25%* |
| II | 26% to 50% |
| III | 51% to 75% |
| IV | >75% |

* Displacement remains within the first quadrant.

and extensibility affect jump-landing-force attenuation capacity, promote lumbosacral malalignment, and increase the load on the bony aspects of the spine. In flexion, gravity provides a forward turning moment on the upper body, which is immediately counteracted by trunk extensor muscle activation that either controls the amount of further forward flexion (eccentric activation) or returns the body to its upright position (concentric activation). In the later stages of flexion, the spinal ligaments become solely responsible for support of the forward moment, while the upper body's weight creates a compressive force at all lumbar spine joints and an anterior shear force at L5-S1. Most muscles that act directly upon the lumbar spine are located at an angle to the intervertebral joints. This positioning produces compressive and shear forces, as well as a turning moment on the intervertebral joints. The L5-S1 joint is equipped with antitorsional characteristics (enlarged transverse processes), so most of the damaging stresses of flexion overload, unbalanced shear forces, and forced rotation occur at the level above it (L4-L5).[26] However, spondylolisthesis is most common at L5-S1 as the pars of L5 fractures or dissolves.[20]

Researchers question whether repetitive microtrauma or improper biomechanics are mainly responsible for the onset of spondylolysis or spondylolisthesis. Many believe that other pathologic or congenital factors predispose the skeletal tissue to injury. Pars lysis is often accompanied by disc degeneration and a shortened spinal posterior ligamentous system.[26] Most experts agree that spondylolisthesis and spondylolysis are more commonly the result of repetitive microtrauma and should not be termed acute fractures, although a single episode of forced hyperextension can sometimes result in an acute fracture of the posterior elements of the lumbar spine.[23]

Many athletes train excessively, train in a neuromuscularly fatigued state, regularly attempt skills that are beyond their physical capabilities, and develop training-induced muscle strength and extensibility imbalances. Either individually or in combination, these factors further reduce the athlete's ability to attenuate the kinetic energy of jump landings, twisting movements, and lifting, promoting greater dependence on noncontractile structures for postural maintenance. This leaves a greater amount of energy, or stress, to be dealt with by noncontractile tissues, such as bone, and adjacent capsuloligamentous structures. When these factors are present during a "growth spurt," the likelihood of sustaining an overuse injury increases. If such activities are practiced repeatedly, these noncontractile tissues can gradually fail, and stress fractures can occur.[27]

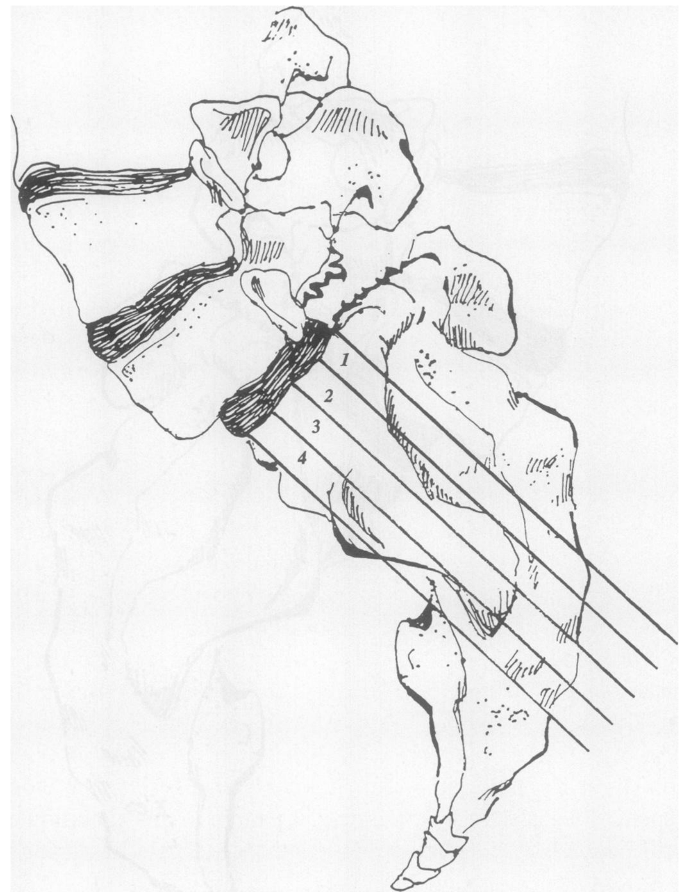

**Figure 5. Meyerding's classification system for spondylolisthesis.[24]**

Reports indicate that athletes who train at a high intensity, with few or no rest intervals, and in excess of 24 hours/week over a period of years increase their risk of developing a pars defect.[27] Such training programs should be modified to include periods of active rest with training-variable manipulations to allow sufficient time for structural adaptations to occur. This is particularly true for the preadolescent and adolescent athlete; however, how much training constitutes too much training remains a matter of debate and warrants further investigation. Conditioning and skill levels can be maintained while allowing active rest of the pars through various low-impact activities, such as aquatic exercises, or through the use of impact-absorbent surfaces to diminish the stresses commonly associated with pars defects. Instruction in proper jump-landing methods may also be useful.[18,28,29]

Pars defects can develop early in life and may have a strong hereditary basis.[27] Although infant cadaver dissections have failed to reveal defects[26] and no clinical evidence of defects in children under 5 years of age has been reported,[8] Wiltse et al[22] have reported an incidence of 40% among children over 10 years of age among members of a 36-family study.[22] The most common age of manifestation on radiograph was between 5 and 7 years, with the period of most rapid vertebral slippage between 9 and 15 years.[22] This information may provide a foundation for modifying the frequency of participation in high-risk sports for this age group, particularly if there is a positive family history.

## CLINICAL EVALUATION

Diagnosis of the cause of low back pain can be difficult, since symptoms usually cannot be related to a single traumatic event and initial radiographs are often normal. Correct diagnosis is imperative, however, since misdiagnosis can lead to permanent disability.[12] Regardless of the magnitude of pars involvement (stress reaction, spondylolysis, mild spondylolisthesis), the following is a representation of possible symptoms and findings in a theoretical athlete's initial evaluation.[8,27]

Subjectively, the athlete complains of mild to moderate low back pain that began as a dull ache but has gradually increased in intensity. He or she may report pain along the posterior belt line, with occasional radiation along the posterolateral thighs and buttocks; however, no specific traumatic history is noted. Observation may reveal a hyperlordotic posture. Athletes with a body build in which the torso appears short, the rib cage appears low and the iliac crests high, the buttocks are flat or heart-shaped (from a relatively vertical sacral position in relationship to the lower lumbar spine and increased bi-iliac diameter), the abdomen protrudes, or there are transverse abdominal creases are more likely to have, or to develop, spondylolisthesis.[25] The classic gait pattern in this condition is stiff legged, with a short stride length due to tight hamstrings, often referred to as the "pelvic waddle."[8,25,27]

Active trunk rotation and twisting, lateral flexion, and repetitive flexion and extension elicit pain; however, this pain is relieved by rest. On examination, trunk flexion is generally pain free, but returning to an upright extended position causes pain. Evaluation of function fails to reveal lower extremity muscle weakness. Poor abdominal muscle strength is noted, however, and this finding correlates highly with the progression of pars conditions.[15] Active hamstring extensibility is usually decreased when the athlete attempts to actively extend the knee from a supine starting position of 90° hip flexion and 90° knee flexion.[1] Iliopsoas extensibility is decreased during the Thomas test.[1] Rectus femoris extensibility is decreased during the modified Thomas test.[1] Neurologic assessment fails to reveal nerve root signs, and all deep tendon reflexes are normal and bilaterally equal. Palpation reveals a possible L5 spinous process step sign (dependent on the degree of spondylolisthesis) and may detect protective lumbosacral paravertebral muscle spasms.

## RADIOGRAPHIC EVIDENCE

Radiographic studies supply the best diagnostic information, with 2 oblique views being necessary to adequately observe a unilateral pars defect. The presence and extent of spondylolisthesis can also be shown with this technique. Oblique films of the lumbosacral spine will usually demonstrate a pars abnormality, depicted as the collar of the "Scotty dog" sign in isthmic defects. Flexion and extension views and cineradiography[9] may be beneficial in determining instability. If standard radiographs are nondiagnostic (failing to show evidence of a fracture line or bone defect) and significant pain or disability, or both, are present, a technetium bone scan can delineate an acute lesion within 5 to 7 days after the onset of symptoms.[8,30] The bone scan is used to separate acute from chronic injuries, with the belief that acute injuries have the capacity to heal. The bone scan can also be used to assess the healing activity of established lesions. A pars defect that appears on initial radiographs requires close observation for evidence of the bony rounding and reabsorption that are indicative of a chronic condition.[8,31] When the athlete can return to activity and at what intensity level are largely dependent upon whether the radiographic evidence is suggestive of an acute or chronic defect. Recurrence of a pars defect has not been reported after the fracture has completely healed and when the bone scan is negative.[6] Single-photon emission computed tomography has recently been found to be useful in identifying pars defects in athletes who are symptomatic but who appear normal during radiographic or scintigraphic examination.[25,32,33] Single-photon emission computed tomography has been shown to be the most sensitive method of diagnosing a pars interarticularis stress reaction or spondylolysis, making possible early intervention to prevent injury progression.

## TREATMENT

Accurate diagnosis when evaluating the acute or chronic nature of a pars lesion must be emphasized, since this will have profound significance for both prognosis and treatment. The treatment approach for spondylolysis or spondylolisthesis depends upon the athlete's age and symptoms and the magnitude of the deformity. In each instance, both conservative treatment modalities for pain and inflammation control and restoration of normal, pain-free function are initiated and progressed as tolerated, with avoidance of postures that replicate the injury mechanism or impact forces.

Pars interarticularis stress reactions that present with a positive bone scan but no radiographic evidence of a fracture line are best treated by restricting activities to pain-free limits and by antilordotic bracing (at least 8 to 12 weeks) to allow the stress reaction to effectively remodel without developing a weak point in the pars.[34] After bracing, another 4 to 6 weeks of conditioning may be required to return an athlete to competition. Patients with this diagnosis are treated conservatively with emphasis on pure healing, while patients with chronic cases of spondylolysis or spondylolisthesis are treated more for symptom reduction, since the likelihood of complete healing is very remote once a true bony defect has occurred.

Adolescents with acute spondylolysis usually respond well to conservative treatment, including a shorter period of antilordotic bracing (4 to 8 weeks) and cessation of activities requiring hyperextension or impact loading of the spine. If diagnosed and treated appropriately, this fracture will not progress to spondylolisthesis. Unilateral spondylolysis is a rare disorder, usually representing an acute spondylolysis that has healed on one side only and producing pain and a positive bone scan only on the unhealed side. When this diagnosis is made, further time and treatment should be considered to achieve bilateral bony healing.

Adolescents with chronic or long-standing spondylolysis who present with recurring back pain are usually immobilized for a shorter period of time (2 to 4 weeks, since complete bony healing is very unlikely), only to relieve the acute pain and spasm. As the pain subsides, the other conservative treatment components are progressed as tolerated. In general, this is also the progression for patients with grade I or II spondylolisthesis.

Conservative methods of treating the pars interarticularis stress reaction, spondylolysis, and spondylolisthesis progression may include custom-fitted thoracolumbosacral orthoses or casts fitted from the chest to the knees to prevent excessive lumbar lordosis.[27] Even in the absence of bony healing, 88% of persons with a pars defect using a thoracolumbosacral orthosis eventually return to sports activities symptom free;[27] however, an additional 3 months of brace use during sports may be needed. Recently, a new surgical method of direct spondylolysis repair has been reported as another viable treatment option that may promote bony healing and earlier return to competition.[35]

Conservative treatment measures are recommended for athletes with low-magnitude lumbar spondylolisthesis without radicular symptoms. Bell et al[34] reported that all of 28 patients with grade I or II spondylolisthesis were pain free and free of radiographic evidence of increased slippage or sacral inclination after, on average, 25 months of antilordotic bracing. Pizzutillo and Hummer[36] concurred that approximately two thirds of adolescents with grade I or II spondylolisthesis improve when treated conservatively. The skeletally immature athlete with spondylolisthesis should be reassessed frequently with plain radiographs to determine if there has been progression of the lesion.

Progression is rare in the skeletally mature athlete, but failure to improve with treatment or frequent symptom exacerbations warrants repeat radiographs to make sure that further slippage has not occurred. Grade I and II slips are usually considered mild in the skeletally mature patient, while grade III and IV slips are more severe, more often cause symptoms, and more often require surgery. Only when conservative treatment measures have been exhausted or when slippage progression is relatively rapid and intractable radicular pain associated with nerve root entrapment is evident are surgical methods such as lumbar fusion recommended.[4] Return to contact sports after lumbar fusion is unlikely because of the limitations placed on the athlete by spinal surgery. If the surgical option is chosen, most orthopaedic surgeons prefer a posterior approach to spinal fusion for the skeletally immature patient with a documented spondylolisthesis progression.

In general, continued spondylolisthesis progression in a skeletally mature athlete denotes segmental instability and probably requires surgery, while progression associated with pain in an immature athlete requires modification of activities or repetitive postures that may promote further slippage, regular radiographic assessment of the lesion status, and symptomatic treatment. In the adolescent athlete, anterior vertebral slippage of less than one third of the vertebral-body width can usually be treated with activity restriction, use of a molded lumbosacral orthosis to promote neutral lumbar alignment, and serial radiographs to monitor for further slippage over a 3- to 6-month time frame. Anterior vertebral slippage of more than one third of the vertebral-body width in an adolescent athlete may warrant surgical intervention, even if the athlete is asymptomatic; however, establishing a definite relationship between pain and segmental instability is recommended before surgery, such as bony fusion or another method of pars stabilization, is performed.[8] Severe cases of spondylolisthesis may also require paravertebral nerve blocks to relieve radicular symptoms from nerve root irritation.[37]

Females and athletes with repeated episodes of spondylogenic low back pain are at greater risk for spondylolisthesis progression, particularly if they present with (1) anterior slippage of greater than 50% of vertebral-body width, (2) a domed or rounded first sacral vertebra, and (3) evidence of an increasing angle between the adjoining surfaces of the involved vertebral pair. As with other conditions, conservative measures including activity restrictions should be exhausted before surgical management is selected.

Most symptomatic athletes can be treated conservatively through proper lumbosacral posture and positioning training, as well as activity modifications.[37] Faulty body mechanics or postures that promote excess lumbar lordosis need to be discouraged.[4] Use of a lumbosacral corset with or without a moldable insert (form fitted in neutral lumbar alignment) may be useful during activities to decrease pain and help teach proper low-back posture and positioning.

Back school programs are a treatment approach that arose out of the belief that low-back injury prevention would be more cost effective than treatment. Back school programs focus on ergonomic adjustments in the work place, proper body mechanics and posture instructions, and strengthening or extensibility exercises for existing imbalances. Effective programs usually comprise all of these components. Although they are generally more effective when implemented for injury prevention, these programs are usually initiated after acute back injury, with the primary goal of facilitating pain-free functional movements and improved kinesthetic awareness of body positions and postures.[2] While a recent study has reported back schools to be limited in their prevention of work-associated low-back injuries, multiple variables (including, but not limited to motivation, perceived secondary gain, compliance, and the establishment of bona fide modifications in "low-back use" behavior) contribute to their effectiveness.[38] Daltroy et al[38] demonstrated that subject knowledge of safe "low-back use" behavior was increased by back school training. By introducing back school concepts to younger individuals in physical education classes and athletics, perhaps behavioral changes can help to prevent the development of pars defects. Teaching proper lifting and jump-landing mechanics and other "back-saving" measures, such as muscle strength and extensibility imbalance correction, may be more effective if they occur concurrently with the development of other motor skills. Presentations in educational settings would also enable more frequent instruction and reinforcement of proper "low-back use" behaviors. These types of interventions could progress from instruction in proper static postures through more dynamic movements, always relating the importance of a healthy lumbar spine to activities of daily living, as well as sports performance. This type of "athletic back school" format may more effectively stimulate the interest of the athlete, and the techniques may become assimilated more effectively than programs that fail to include improved performance connotations.

Athletes who experience mild to moderate low back pain benefit greatly from relaxation techniques, including ice or moist heat, nonsteroidal anti-inflammatory medications or muscle relaxants, and brief bed rest to alleviate initial acute pain, inflammation, and anxiety.[4,37] As soon as possible, these measures should be implemented in conjunction with progressive active low-back mobility challenges, preferably within the context of the athlete's sport and position or event. Exercises (as the ultimate treatment modality) should be initiated with the focus on dynamic spinal stabilization, where the patient learns to maintain a neutral lumbar alignment during various movement challenges and perturbations.[2] Abdominal and low-back musculature strengthening[4] and hip-muscle extensibility (with special emphasis on the iliopsoas muscles and hamstrings) should also be considered.[8] Trunk-flexion exercises have been found to be more effective than trunk-extension exercises for pain relief among athletes with spondylogenic disorders. Caution should be used with lumbar intervertebral joint mobilizations to avoid creating pain that radiates to the lower extremities (indicative of possible lumbar disc and spinal nerve involvement).

## SUMMARY

Since athletes will continue to train through lumbar spine pain in an effort to achieve or maintain competitive status in their specific sport, they must be closely and constantly scrutinized for pars defects. Early detection of the defect is essential to a complete and expedited recovery. Ignoring the signs and symptoms of a pars defect is a tremendous mistake. Consider pain a warning sign for potential lumbar vertebra damage that could lead to permanent disability.[1] The pars interarticularis stress reaction, spondylolysis, and spondylolisthesis progression can often be prevented or at least managed effectively if clinicians acknowledge its multifactorial basis. Optimal management should include screening for high-risk individuals based on family history or somatotype, education in "back-saving" measures, nutritional counseling, avoidance of overtraining, and establishing a normal interplay of trunk and lower extremity muscle strength, endurance, and extensibility. Postural training encouraging proper lumbosacral alignment and avoiding excessive posterior vertebral loading during static postures and positions is important, as is increased use of the lower extremity musculature during jump landings and overhead lifting.

Competitive female athletes, particularly gymnasts and cheerleaders, may be particularly at risk for developing spondylolisthesis due to both the movement and training demands of their sport and the interactive effects of the hormonal changes associated with menarche. Future research needs to focus on female athletes' fracture risk related to menstrual irregularities. Careful consideration should be given not only to promoting exercise as beneficial but also to identifying the female athletes who are at risk for decreased bone mineral density. Once these athletes have been identified, therapeutic measures should be instituted to improve nutrition, modify activities, and implement a corrective exercise regimen.

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